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An empirical model for defluoridation by batch monopolar electrocoagulation/flotation (ECF) process

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Abstract

Excessive presence of fluoride concentration in community water supplies can cause fluorosis that affects the teeth and bones. Batch experiments with monopolar aluminium electrodes for fluoride removal were conducted and an empirical model is developed using critical parameters such as current concentration, electrode distance, and initial fluoride concentration. Fluoride ions were removed electrochemically from solution by electrocoagulation/flotation (ECF) process. The electrolytic dissolution of aluminium anodes in water produced aqueous Al^{3+} species and hydrogen bubbles at the aluminium cathodes. The fluoride removal efficiency increases steadily with increasing current values from 1 to 2.5 A. In the batch monopolar ECF process, the optimal detention time (d_{to}) was found to be 55 min when the operational parameters including initial F^- concentration, current value, and inter electrode distance were respectively kept at 10 mg/l, 1.5 A, and 5 mm. The experimental results showed that the rate constant (K) for defluoridation by monopolar ECF process depends on the current concentration (I/V), electrode distance (d) and initial fluoride concentration (C_0). The Al^{3+}/F^- mass ratio is found to be not significantly different between monopolar and bipolar ECF systems. Overall, the results showed that the electrocoagulation technology is an effective process for defluoridation of water.

Keywords: Water treatment; Monopolar electrocoagulation/flotation (ECF); Defluoridation efficiency; Empirical model; Aluminium electrodes

1. Introduction

Most groundwaters have low or acceptable concentration of fluoride (<1.5 mg/l) in the world [1]. In groundwater, the natural concentration of fluoride depends on the geological, chemical and physical characteristics of the aquifer, the porosity and acidity of the soil and rocks, the temperature, the action of other chemical elements, and the depth of wells. Due to these variables, the fluoride concentrations in groundwater can range from less than 1 mg/l to more than 35 mg/l. In India and Kenya, concentrations up to 38.5 and 25 mg/l have been reported, respectively. The total number of people affected is not known, but an estimate would number in the tens of millions. In 1993, 15 of India's 32 states were identified as an endemic for fluorosis. A study by UNICEF shows that fluorosis is endemic in at least 27 countries across the globe [1]. These countries are: Algeria, Argentina, Australia, Bangladesh, China, Egypt, Ethiopia, India, Iran, Iraq, Japan, Jordan, Kenya, Libya, Mexico, Morocco, New Zealand, Palestine, Pakistan, Senegal, Sri Lanka, Syria, Tanzania, Thailand, Turkey, Uganda, and United Arab Emirates. In Australia, the fluoride concentration was recorded 13 mg/l in a water bore near Indulkana region; however, it is not used for human consumption [2].

Health impacts from long-term use of drinking water with a high fluoride concentration have been summarized in Table 1 [3,4]. The maximum acceptable concentration of fluoride in water is 1.5 mg/l. Fluoride also can be found in industrial wastewaters, such as in glass manufacturing industries [5] and in high concentrations in semiconductor industries [6]. The discharge of these wastewaters without treatment into the natural environment may also contribute to groundwater contamination. To control fluoride concentrations in drinking water, several treatment options exist. A number of defluoridation processes, such as adsorption [7], chemical precipitation [8], electrodialysis [9], and electrochemical methods [10,11] have been tested globally. In the precipitation technology, alum or combination

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